Cotton Crop Production

PHILIP J. BAUER, *USDA-Agricultural Research Service, South Carolina*

Glossary

Anthesis Opening of the flower with flower parts ready for pollination
Cutout Temporary stage in cotton crop development when vegetative growth and flowering are arrested as bolls develop on the plants
Ginning Removing seeds from harvested cotton with either rollers or saw-blades
Monopodial branches Branches arising from the main stem of cotton that resemble the main axis in that they grow vegetatively and also produce sympodial branches; also called vegetative branches
Seed cotton Cotton seed with the lint attached
Square Cotton flower bud
Sympodial branches Branches arising from the main axis or monopodial branches that have flower buds; also called reproductive branches

Cotton crop production research deals with determining relationships between biotic and abiotic factors that influence crop growth and development and formulating production schemes from that information. Economic and environmental benefits and constraints are considered by researchers.

I. Introduction

Cotton is grown in many diverse environments around the globe. In the United States, cotton is grown in areas with 180 or more frost-free days per year. Since growing conditions differ considerably across the U.S. Cotton Belt, local environmental conditions dictate optimum management practices for a specific region. Some practices, such as pest control and nutrient fertility, can only be optimized on a field by field basis.

Cotton is somewhat unique among the four major agronomic crops in the United States (corn, wheat, soybean, and cotton) because of the emphasis placed on crop quality. Fortunately, many practices that maximize seed yield of cotton also result in highest lint quality. Management decisions at specific periods in the development of the cotton crop help determine final yield and quality.

Cotton lint yield is primarily a function of the number of bolls per unit land area, the size of the bolls, and the ratio of lint to seed in the bolls. Cotton quality is a function of the characteristics of the fiber and the amount of trash or foreign material in the lint. Fiber properties influence the efficiency of the spinning process and the quality of the yarn product. Production practices and genetic factors influence both yield and quality to varying, but interactive, degrees.

Physical characteristics of cotton lint provide a measure of quality of the bale to textile manufacturers. High-quality cotton lint has long, strong fibers that are uniform in length. Fiber strength is determined by measuring the force required to break a small bundle of fibers. Micronaire, a measure of fiber fineness, is determined by measuring air flow through a small sample of fibers. It approximates the average weight of the individual fibers in micrograms. Mature fibers that have low micronaire are desirable, but low micronaire caused by immature fibers reduces quality because immature fibers do not accept dye readily. [*See* COTTON PROCESSING AND UTILIZATION.]

II. Cotton Crop Development

Cotton is seeded in the spring when soil temperature and moisture are adequate for germination. After imbibition, the radicle emerges from the seed and grows down into the soil. Hypocotyl elongation begins shortly thereafter, pulling the cotyledons toward the soil surface. Once the hypocotyl hook reaches the soil surface, the hypocotyl straightens and the cotyledons expand and become photosynthetic organs.

The development of the root system is impacted by a number of factors, including cotton cultivar, soil environmental conditions (i.e., moisture, strength, temperature, aeration), and above-ground processes such as photosynthesis, leaf area development, and fruiting. Cotton is a taprooted plant with a primary root that may grow to depths of several meters. Secondary roots begin developing several days after germination. The secondary roots, which account for most of the root surface area, absorb most of the water and nutrients.

Early above-ground cotton growth is slow compared to that of other crop plants because there is no plumule above the cotyledons in the germinating seed. True leaves form at each node above the cotyledonary node, and two axillary buds (the second usually remaining dormant) form at the base of each true leaf. Two types of branches form on the main stem from the axillary buds. Vegetative (monopodial) branches generally form on the lower nodes of the main stem and their morphology is similar to the main stem. Once flower induction has occurred, reproductive (sympodial) branches form from the axillary buds. This generally commences between the 5th and 10th main stem nodes. Sympodial branches differ from monopodial branches in that the growing point of each branch terminates in a flower. Subsequent extension of the branch occurs from the axillary bud at the base of the leaf that arises with each flower.

The terminal axis on the main stem of the cotton plant remains vegetative throughout the development of the crop. Thus, both vegetative and reproductive growth occur simultaneously until sufficient bolls are produced to act as metabolic sinks resulting in diversion of nutrients and photosynthates from the terminal axis. The period of time during boll development when vegetative growth stops is called cutout. When the older bolls mature and are no longer active as sinks, vegetative growth resumes in response to increased availability of water, nutrients, and photosynthate.

The first small squares are visible on the short sympodial branches in the terminals of the plants, usually about 30 days after planting. About 3 weeks later, the first open bloom will appear in the field. At about 45 days after flowering, the bolls reach maximum dry weight (maturation). From flowering to mature boll, the bolls accumulate nutrients and photosynthates as the seed and fibers grow. Many technical reports use days past anthesis as a parameter to describe age of the boll. As bolls dry, carpel walls dehisce along sutures, exposing the seed cotton.

The bloom period (the time from first bloom until the last bloom that can be expected to mature before harvest) is a critical time in the development of the cotton crop. This developmental period may be as short as 2 to 3 weeks in a short growing season environment to longer than 6 weeks in a long season environment. Cotton bolls are especially susceptible to stress-induced shedding from 1 to 15 days after flowering. Environmental conditions during this period also affect fiber growth and, thus, fiber properties.

Cotton fibers are formed from single epidermal cells on the seed coats. The majority of the fibers are initiated at the day of anthesis. After anthesis, the fibers cells elongate through extension of the primary cell wall for about 16–19 days. Secondary wall formation, which occurs inside the primary wall, results in fiber thickening. Wall thickening begins shortly before the fibers cease elongating and continues until boll maturation.

The rate of development of the cotton crop is highly temperature dependent. Several methods are used to predict major morphological stages of the cotton crop. These include totalling accumulated days from emergence, heat units, and total hours above 17°C. Fairly accurate predictions of major crop morphological events can be made by using these methods under stress-free conditions of a given cultivar. However, both abiotic (e.g., lack of moisture or nutrients) and biotic (e.g., weed, disease, and insect infestations) stresses reduce the accuracy of these prediction methods.

Predicting crop growth stages is important if growers are to prepare and follow management schemes for maximum cotton production. Some of the important developmental stages for the crop are the date of emergence, the appearance of first true leaf, the first square, the first flower, the first open boll, and the time when all bolls are open. The predictability of the crop growth stages has led to the development of computer growth simulation models that are currently used as management tools. Simulation models are used to determine when sidedressings of nitrogen fertilizer, irrigation, and defoliation chemicals should be applied. Model use has been limited, however, due to an inability to simulate accurately the growth of cotton that has been stressed by insects or lack of moisture. Appropriate incorporation of biotic and abiotic stress factors in these models will greatly enhance their usefulness to growers.

III. Influence of Cultural Practices on Yield and Fiber Quality

Numerous studies have been conducted to determine the optimum cultural practices for producing cotton. New and emerging technologies in growing, grading, and spinning fiber require that these management practices be constantly updated. Federal and state regulations relating to pesticides and erosion control increasingly govern which technologies growers can employ.

A. Cultivar Selection

Improvement of cotton through plant breeding is hampered because many traits, including lint yield, fiber properties, and insect resistance, are quantitatively inherited. Variety development is also hindered by frequently observed and significant genotype by environment interactions. This suggests that choice of cultivar should be based on expected local growing conditions, such as moisture, temperature, and disease stresses. [*See* CULTIVAR DEVELOPMENT.]

Two types of cotton cultivars are grown in the United States. In the West, mid-South, and East, cultivars have seed cotton that is easily detached from the bolls and can be harvested with spindle pickers. High winds can dislodge the seed cotton from the bolls prior to harvest in the west Texas and Oklahoma regions, and cultivars have been developed for those areas that hold the seed cotton firmly in the boll after boll opening. These cultivars are known as stripper types since harvest consists of stripping all parts of the bolls from the plant.

Other morphological traits may make a cultivar more suitable to specific locations. Okra-leaf cotton has deeply lobed leaves that allow more air movement within the canopy, thus decreasing the incidence of boll rot. In humid south Louisiana, this leaf characteristic results in higher yield for okra-leaf types than normal leaf cottons in some years.

Fiber properties are more genetically controlled than is yield, but environmental conditions also influence fiber quality. To be marketable in the United States, a cultivar must have acceptable fiber properties, and grower cultivar selection for fiber characteristics may increase net returns if cultivars are chosen that are consistently in the premium ranges for micronaire and fiber strength.

Several advances in plant breeding technology will have great impact on future cotton cultivars. It appears that the negative genetic linkage between cotton yield and fiber strength has been broken, and germplasm is available that will allow breeders to increase these two traits simultaneously. Transgenic cotton varieties with both pest and herbicide resistance will soon be available. Cotton cultivars with the Bt gene (a gene from the bacteria *Bacillius thuringiensis* which produces a protein that is poisonous to lepidopterous insects) will reduce the amount of insecticide needed to produce a crop. Herbicide-resistant cultivars in development will allow more effective weed control than do current weed control options. These herbicide-resistant cultivars may also increase the use of conservation tillage for cotton production by improving weed control.

B. Planting Date

The fate of a cotton crop in a given year depends on the environmental conditions that occur between planting and either harvest or the first killing frost. Temperature, the amount and timing of precipitation (under rainfed conditions), and total solar irradiation are major determining factors of the yield and fiber quality of cotton.

Generally, early planting of cotton is recommended to utilize the entire growing season, to reduce the damage by and aid in the control of insect pests, and to avoid late season storms. Cotton is sensitive to cold temperature stress, and planting too early can result in reduced stands. Seedling disease problems increase when cotton is planted in soil where the temperature is suboptimal. Recommendations vary, but generally soil temperatures should be at least 15.6°C at 25 cm below the soil surface to avoid root damage and seedling disease problems.

Late-planted cotton may grow excessively tall and produce too much vegetative growth, increasing problems with boll rot and defoliation. In many areas, the threat of an early-season freeze makes late planting inadvisable. In areas where the boll weevil (*Anthonomus grandis*) and pink bollworm (*Pectinophora gossypiella*) remain important pests, late-planted cotton serves as a food source for diapausing insects and results in increased pest populations the following year.

The impact of planting date on fiber quality is less well defined. Early planting results in bolls developing earlier in the season when temperatures are higher. Generally, fiber from bolls that develop under higher temperatures will have higher micronaire and be shorter. Intermittent drought periods can play a major role in determining fiber properties since moisture stress can reduce both micronaire and fiber length. Intermittent stresses may be more important in late-planted cotton where the effective period for both flowering and boll set is shorter.

C. Seeding Rate

Increasing plant density increases competition between plants for nutrients, water, carbon dioxide, and light. As plant densities increase, cotton plants grow taller with lower stem diameter, fewer branches, and lower plant dry weight.

Optimum seeding rate is determined by environmental conditions, especially available moisture. Cotton plant stands range from 100,000 to 250,000 plants per hectare, depending on growing conditions. Early-planted cotton is seeded at higher rates than late, since early planting frequently increases seedling losses due to cold temperature stress and seedling disease.

Most cotton is currently planted in rows that are 0.91 to 1.07 m wide. Until recently, spindle picker technology has limited cotton production in narrower rows. In the late 1980s, equipment manufacturers began selling spindle pickers that could harvest narrow-row cotton. Current research is determining the optimum seeding rates for narrow-row production.

The influence of plant density on fiber properties is small. Micronaire can be decreased by high plant stands, but other fiber traits appear to be independent of plant density. Low plant populations reduce the efficacy of weed control programs and increase the amount of weeds in harvested lint, thereby reducing fiber quality.

D. Tillage Systems

A well-prepared seedbed has long been recognized as a necessity for obtaining good stands of cotton. This has generally been accomplished with conventional tillage systems. However, recent improvements have been made in equipment to accurately place seed in soil that has large amounts of surface residue. This makes conservation tillage systems a viable option for producers. [*See* TILLAGE SYSTEMS.]

Conventional tillage is generally described as complete incorporation of all surface plant residues. Implements for this system include moldboard plows and heavy disc harrows. Conservation tillage systems leave some or all of the plant debris on the soil surface to protect the soil from wind and water erosion. Chisel plows and light disc harrows are often used to loosen the soil but keep some residues on the surface. A form of conservation tillage where soil only in the row is disturbed is called "no-tillage." Usually, any tillage that occurs in no-tillage is with shovels or coulters attached to the planter bar to loosen the top few centimeters of soil directly in front of the planter unit. This tillage method provides the most soil protection since nearly all plant residues remain on the surface.

Weed control is one of the main reasons conventional tillage remains the norm in cotton production. Deep tillage with a plow or disc harrow buries some weed seeds too deep for germination. Between-row cultivations is an effective method for reducing weed populations in fields. For conservation tillage systems, new implements have been developed to cultivate weeds in row middles of fields with large amounts of surface residues. Some of these cultivators can be adjusted so that most of the plant residues remain on the surface after cultivation.

Tillage is also used to control other pests by the elimination of overwintering sites. Early harvest with stalk destruction and incorporation of cotton plant residues is used to reduce populations of overwintering boll weevil and pink bollworm where these insects are present. Control methods for bacterial blight (*Xanthomonas malvacearum*) include incorporating all cotton plant residues in the soil.

Clean tillage has also been considered necessary on land that is furrow-irrigated. With furrow irrigation, row middles might need to be made free of debris before water is applied if the water is to flow through the field. Land planing is done periodically to provide the correct slope for even distribution of irrigation water through a field. Research is in progress to develop conservation tillage cotton production systems in areas of the cotton belt that use furrow irrigation.

Some form of deep tillage is needed on land that has a natural or tillage-induced hardpan. Some of the most productive soils in the southeastern U.S. Coastal Plain are characterized by a dense E horizon which becomes impenetrable to roots when it dries. Other soils throughout the Cotton Belt become root restricting under tractor and implement traffic. These soils can generally be loosened with in-row subsoiling which consists of pulling a thin shank through the soil to a depth below the hardpan layer (generally 20 to 60 cm).

Although conventional tillage is used on most of the land planted to cotton, interest is increasing in the production of cotton with reduced tillage systems. Reduced tillage systems are used for compliance with federal legislation directed at reducing soil erosion on highly erodible land (HEL) and for reducing production costs. In addition to soil erosion control and reduced production costs, reduced tillage systems, often increase soil organic matter in the top few centimeters. Higher amounts of organic matter combined with surface residues may result in increased soil nutrient status and increased rainfall infiltration and retention.

Lack of dependable weed control technology is probably the most important reason growers have not adopted conservation tillage in cotton production. With some conservation tillage systems, especially no-tillage, weed control is limited to using currently available herbicides. Most soil-active pre-emergence herbicides need precipitation or irrigation to move into the soil. Under rainfed production systems, both the yield and the quality of the cotton crop are threatened if environmental conditions reduce the effectiveness of these herbicides.

Research results indicate little yield difference between conventional and conservation tillage systems. In some areas, such as the Texas High Plains and Oklahoma region, conservation tillage has resulted in increased yields because standing stubble protects young seedlings from damage by wind and blowing sand. Also, increased soil moisture found in conservation tillage systems can result in higher yield. In highly erodible areas, reduction in losses of soil, nutrients, and organic matter with conservation tillage can result in increased yield.

Tillage systems, by themselves, do not appear to have a major impact on fiber properties. Changes in the environment of the cotton crop as a result of using a specific tillage system may influence fiber quality. For example, inadequate weed control in conservation tillage systems may increase the amount of stained lint and foreign matter in cotton, thereby reducing quality.

E. Irrigation

Supplemental irrigation is necessary in a number of cotton-producing areas around the world. In the United States, areas in west Texas, New Mexico, Arizona, and California depend on irrigation for cotton production. In traditionally rainfed cotton production areas, growers are also installing irrigation systems to decrease the risk associated with periodic droughts. [*See* IRRIGATION ENGINEERING: FARM PRACTICES, METHODS, AND SYSTEMS.]

The predominant methods for application of supplemental water to cotton are furrow (and basin) and overhead sprinkler irrigation. In furrow-irrigation systems, water is applied through gated pipes on one end of the field and allowed to flow down row middles. Overhead sprinkler systems travel through the field applying water above the canopy.

In many cotton-growing areas, supplies of irrigation water are dwindling and new irrigation technologies are emerging in response to lower water supply. Low-volume, high-efficiency overhead sprinkler systems have been developed. Micro-irrigation tubing, which can be buried or placed on the surface, is being studied as a possible option. This method, also called drip or trickle irrigation, places small amounts of water in the rooting zone of the plants, eliminating water loss through evaporation and through leaching. In humid areas, the water table can be manipulated by using dams on streams to keep subsoil moisture at an optimum level. Cost of installing micro-irrigation and controlled water table irrigation systems limits their use by growers. [*See* IRRIGATION IN HUMID REGIONS.]

Among crop plants, cotton is one of the most tolerant of dry soil conditions, but it responds well to water application. Timing of water stress appears to be more important than total amount of water available to the crop. During early seedling growth, cotton can withstand long periods with minimal water and yield will not be greatly affected. Once squaring begins, however, periods of prolonged water stress will cause square and boll abortion and dramatically affect yield. Data from Arizona indicate that young bolls (less than 5 days old) will abscise when water potential of the uppermost fully expanded leaf reaches about -1.8 Megapascals. Early square and boll shedding is especially important in areas with short growing seasons since the plants may not have enough season left to develop more bolls at the top of the canopy.

Severe soil water deficit can reduce fiber length and micronaire. Since cotton responds to water stress by abscising squares and bolls, few bolls develop under severe water stress conditions. Thus, the impact of water stress on fiber properties appears to be small compared to that on lint yield.

F. Mineral Nutrition

Like all plants, the response of cotton to mineral elements is largely determined by other environmental factors, such as light, temperature, and water availability. Yield expectations play a major role in determining fertilizer recommendations by state extension specialists. Although estimates vary, plant uptake for modern cultivars is in the range of 10–20 kg nitrogen, 1.3–2.6 kg phosphorous, and 9–15 kg potassium for 100 kg lint. [*See* Soil Fertility.]

Nitrogen management is a key aspect of cotton production because both limited and excess nitrogen can reduce yield. Nitrogen deficiency can reduce photosynthetic rates, growth rate, leaf area, and seed size. Excessive vegetative growth occurs when nitrogen levels are too high, leading to square and boll shedding through mutual shading of leaves. Excessive vegetation is also conducive to boll rot in humid environments. Under rainfed conditions, nitrogen must be managed so that a deficiency occurs at the end of the season. This makes chemical defoliation prior to harvest more effective. [*See* Nitrogen Cycling.]

Phosphorous and potassium deficiencies can also reduce yield by limiting plant growth. Excesses of these nutrients in the soil interfere with the uptake and utilization of mineral micronutrients and can reduce yield through micronutrient deficiencies.

Soil testing and plant tissue monitoring are two methods currently being used to make fertilizer recommendations. Recommendations based on soil tests provide adequate amounts of lime, phosphorous, potassium, and most micronutrients, but nitrogen is highly mobile and readily leached. Plant tissue tests of leaf petioles or leaf blades from a week before flowering through the bloom period can indicate nitrogen deficiencies and sometimes are used to prescribe sidedress or foliar fertilizer nitrogen applications to correct deficiencies. [*See* Fertilizer Management and Technology; Soil Testing.]

Annual recommendations for some micronutrients are made for certain soil types. For example, in South Carolina annual applications of 11.2 kg sulfur per hectare and 0.45 kg boron per hectare are recommended on sandy soils low in organic matter.

The primary effect of added nutrients is on yield, but improper nutrient application rates may also affect fiber quality. Nitrogen deficiency increases micronaire of a bale of cotton, partly because fewer low micronaire bolls are formed in the top of the canopy. Excess nitrogen may reduce defoliant efficacy and encourage regrowth after cutout, thereby increasing the amount of trash in the lint. Potassium influences water transport at the cellular level; water uptake by fiber cells is essential for cell elongation. Therefore, severe potassium deficiency can reduce fiber length.

G. Pests and Pest Management

Pest management is one of the most important concerns of growers throughout the crop growing season. Weeds, insects, diseases, and nematodes cause severe economic losses each year in the form of reduced yield and fiber quality. In addition, pest control through the purchase of pesticides and the use of other weed control practices is a major annual expense for cotton producers.

Pest control measures include cultural methods, host plant resistance, biological controls, and chemical controls. Cultural methods are designed to optimize growing conditions of the cotton crop. Mechanical methods physically remove or kill the pest. Biological control methods include the use of natural predators and parasites to control pests and the selection of cultivars resistant to pests. Chemical control is the use of pesticides. Many growers use a combination of these methods each year, using the principles of integrated pest management (IPM) to control pests. [*See* Integrated Pest Management; Pest Management, Biological Control; Pest Management, Chemical Control; Pest Management, Cultural Control.]

1. Weeds

The most noticeable way weeds reduce cotton yields is through competition with cotton plants for light, nutrients, and water. Weed competition is most severe when plants are young. Studies have shown that weeds must be controlled for the first 6 weeks after cotton emergence or significant yield reductions can occur. [*See* Weed Science.]

Some weeds also serve as alternate hosts for insects, diseases, and nematodes. As already discussed, weeds can significantly reduce cotton fiber quality by increasing trash content of fiber and causing lint stains.

Although local conditions dictate the major weed species in an area, some weed families cause damage throughout the U.S. Cotton Belt. Some of the most difficult to control families include Convolvulaceae (bindweed and morningglories), Cyperaceae (nutsedges), and Gramineae (annual and perennial grasses). Other weed families, such as the Amaranthaceae (pigweed), occur throughout the Cotton Belt but are not serious pests in all cotton-producing areas.

Chemical methods of weed control (herbicides) are used on almost all land where cotton is produced in the United States. Most land is treated with more than one herbicide to control the wide variety of weed species that occur in cotton fields. A number of herbicides are registered for use in cotton. Some of the most commonly used today are trifluralin and the arsenical compounds, monosodium methylarsonate (MSMA), and disodium methane arsonate (DSMA). [*See* HERBICIDES AND HERBICIDE RESISTANCE.]

Currently, growers often use a combination of methods to control weeds. Cultural methods now being used include crop rotation, use of high-quality, weed-free seed, variety selection, plant spacing, and proper plant nutrition. Mechanical methods include tillage for seedbed preparation and cultivation to destroy weeds in row middles. Few biological methods have been successful for weed control in cotton because the cost of development is high and biological agents are usually specific to one weed species.

Concerns about the fate of herbicides in the environment and the increasing regulatory pressures on chemical applications to agricultural land have resulted in an increase in investigations on alternative weed control methods. Preherbicide era weed control technology, such as the use of cover crops and flame cultivation, which scorches young weeds under growing cotton, are being tested to determine their potential as weed control methods with modern production practices.

2. Insects

Yield reductions by insects can be caused by attacks on vegetative plant parts that lead to delayed or reduced growth. Insect attacks on reproductive structures reduce yield by decreasing the number of bolls harvested. Defoliation by some insects, such as whitefly (*Bemisia* spp.), can reduce boll size and may cause plant death. Honeydew falling on open bolls from aphid (*Aphis* spp.) and whitefly infestations late in the season cause sticky cotton and seriously reduce fiber quality.

Major insect pests in cotton include boll weevil, cotton bollworm (*Helicoverpa zea*), tobacco budworm (*Heliothis virescens*), pink bollworm, thrips (*Frankliniella* spp.), plant bugs (*Lygus lineolaris*), fall armyworm (*Spodoptera frugiperda*), and aphids. As with weeds, regional environmental conditions influence the kinds and severity of insect pests in that region.

Stalk destruction is used to reduce the number of overwintering boll weevils and pink bollworms. Several cotton improvement programs are evaluating genotypes for resistance to major insect pests. Transgenic cotton that contains the Bt gene, previously mentioned in this article, will be available to growers in the near future.

The predominant insecticides used in cotton are the pyrethroids, organophosphates, and carbamates. Some insect species have developed insecticide resistance as a result of the reliance on one type of chemical for control. For example, in some areas tobacco budworms have become resistant to the pyrethroid insecticides. When resistance to the pyrethroids was found in this pest, knowledge of insect physiology, population genetics, insecticide toxicology, and insect control methods were combined in the development of resistance management systems.

A boll weevil eradication program is having a large impact on cotton insect pest management in the southeastern United States. Where the boll weevil has been eliminated as an economic pest, the number of insecticide applications has been reduced by 50% or more. This program may eventually encompass the entire Cotton Belt.

Many insect management programs now include identifying and quantifying beneficial insects (naturally occurring predators and parasites of pest species) in a cotton field as well as identifying and quantifying pests. Population counts of both types of insects are used to determine the need for chemical control. With reduced use of organophosphate and carbamate insecticides in areas eradicated of boll weevil, the role of beneficial organisms in pest control may be greatly increased.

3. Diseases

Disease agents (fungi, bacteria, and viruses) reduce cotton yield by decreasing stand, retarding crop growth, and causing boll rot. Quality of the harvested cotton is reduced when diseased bolls are harvested with the rest of the crop. Major diseases of cotton in the United States include seedling disease complex, which is caused by a number of seed-borne or soil-borne organisms, *Verticillium* and *Fusarium* wilts, *Phymatotrichum* root rot, bacterial blight, and boll rots. [*See* PLANT PATHOLOGY.]

Development of cultivars that are resistant to or escape these pest organisms is a major focus of disease control in cotton. Cultural control methods include clean tillage to destroy residues that may serve as a source of inoculum, planting disease-free seed, and crop rotation. Chemical control include fungicides and soil fumigants. A biological disease control product currently available to growers is *Bacillus subtilis*.

This product helps reduce disease caused by *Rhizoctonia* spp. and *Pythium* spp. in seedlings. [*See* FUNGICIDES.]

4. Nematodes

Root-knot (*Meloidogyne incognita*), reniform (*Rotylenchulus reniformis*), lance (*Hoplolaimus columbus* or *H. galeatus*), and sting (*Belonolaimus longicadatus*) nematodes cause extensive yield decreases in cotton each year. Nematodes parasitize plant roots and decrease plant vigor. Yields of infested fields can be depressed by nematode parasitism, even when the plants may not exhibit characteristic symptoms. Also, because symptoms of nematode parasitism are similar to those of water and nutrient stress, infestations are often misdiagnosed. Soil testing is necessary to identify nematode problems.

Interactions between nematodes and fungal disease organisms are prevalent in cotton production fields. Presence of root-knot nematodes increases the severity of wilt caused by *Fusarium oxysporum* and *Verticillium dahlie*. In the case of *Fusarium,* eliminating the nematode problem through host plant resistance or nematode control measures severely diminishes the problem, but controlling the fungi is not sufficient protection from the complex. Nematodes also increase the amount of seedling disease caused by *Rhizoctonia solani*.

Crop rotation and fallowing are used to reduce nematode reproduction on nonhost crops. Chemical methods include the use of fumigant (such as 1,3-dichloropropene) and nonfumigant (such as aldicarb) nematocides to reduce early season populations in the soil. This allows early root growth to be free of nematode damage and reduces the number of generations of nematodes in a season. [*See* NEMATICIDES.]

H. Plant Growth Regulators

Plant growth regulators are organic compounds other than nutrients that affect physiological processes of plants when applied in small concentrations. In cotton production, plant growth regulators are used to control plant vegetative development and to speed opening of bolls in the fall.

The cotton plant can produce excess vegetative growth with favorable soil moisture and high soil fertility. Excess growth can lead to boll and square shedding due to mutual shading of leaves and, under humid conditions, increase the incidence of boll rot. Mepiquat chloride is used on cotton to control excess growth.

Mepiquat chloride is an anti-gibberellin compound that reduces leaf expansion and shortens internodes. This allows greater light infiltration into the cotton canopy and allows more early bolls to set. Mepiquat chloride is applied between first square and first flower, often in multiple applications.

Since the application of mepiquat chloride occurs prior to much of the cotton plant growth, yield responses to application have been variable. When climatic and plant nutrition conditions following mepiquat chloride application are favorable for rank growth, some yield increase may be realized. However, if moisture stress conditions prevail following application of the plant growth regulator, yields may be decreased because of the growth-inhibiting properties of the chemical.

Under humid conditions excessive vegetative growth of cotton results in an increase in boll rot. Controlling vegetative growth with mepiquat chloride increases air movement within the canopy and reduces the incidence of this disease.

Ethephon is a plant growth regulator that stimulates ethylene production in plants. Ethylene hastens boll opening. The accelerated boll opening allows an earlier, once-over harvest in short-season cotton production systems.

Ethephon is applied late in the season after all bolls are mature (when about 65% of all bolls are open). Earlier application may reduce yield by stimulating opening of immature bolls. Fiber properties are not generally affected by application of ethephon unless application is made before bolls are mature. Harvest of immature opened bolls will reduce yarn quality because immature fibers do not readily accept dye.

I. Defoliation and Harvest

Prior to the use of mechanical harvesters, cotton was relatively free of extraneous material because bolls were picked by hand and clean seed cotton was taken to the gin. Coincident with the use of mechanical pickers, removal of leaves prior to harvest became an important cultural practice. Leaves in harvested cotton reduce the quality of the lint and can negatively affect prices received by growers. Excessive leaves in lint increases the amount of cleaning needed, and each cleaning process reduces fiber quality.

Chemicals used to remove leaves from cotton plants include organophosphorus compounds, sodium cacodylate, dimethipin, and thidiazuron. When weed populations are high, desicants, such as paraquat, are sometimes used to remove leaves and also reduce the amount of weed plant material in the harvested lint. Defoliants vary in capacity to defoliate and their capacity to inhibit regrowth in plant terminals. Since defoliation is a physiological process, both rate and degree of defoliation are temperature dependent. Low night temperatures reduce the efficacy of defoliation compounds.

Timing of defoliant application to the cotton crop continues to be researched because of its importance to yield and quality. If defoliant application occurs before all harvestable bolls are mature, yield will be reduced. Defoliating after the optimal time is also detrimental since the weight and quality of open bolls can decrease the longer they are exposed to the environment. Current research on defoliant application timing includes evaluating crop monitoring and computer simulation techniques.

Cotton harvest begins after the leaves are removed from the plants. Harvest in the United States begins in late July in south Texas and continues through November in the northern cotton growing areas. After harvest, seed cotton has historically been placed in trailers and taken immediately to local gins for removal of the seeds from the lint. This could limit the rate that fields could be harvested to the processing capacity of the gin.

To avoid this delay in harvesting, moduling was introduced in the early 1970s as a method of storing cotton on-farm. Cotton moduling consists of tightly packing seed cotton with a module builder, placing a tarpaulin over the cotton, and storing it in a well-drained area of the field. A typical module usually consists 12 to 14 bales of picked cotton or 8 to 10 bales of stripped cotton. By allowing storage of the harvested cotton on the farm, moduling allows continuous harvesting regardless of the processing status of the gin.

IV. Conclusion

From variety selection to harvesting, management decisions made by growers influence the profitability and sustainability of cotton crop production. Advances in biotechnology, production practices, and computer simulations will aid growers in making these decisions. The goal of most cotton production research will continue to be the development of new products and techniques to increase profitability, maintain or increase lint productivity and quality, and protect environmental resources.

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